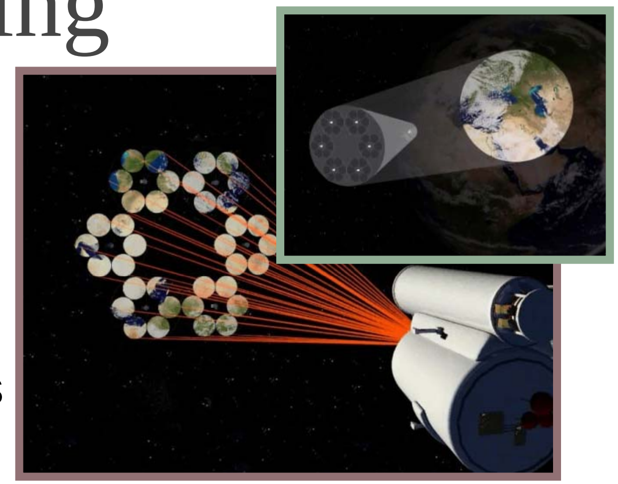
Future Technology Directions

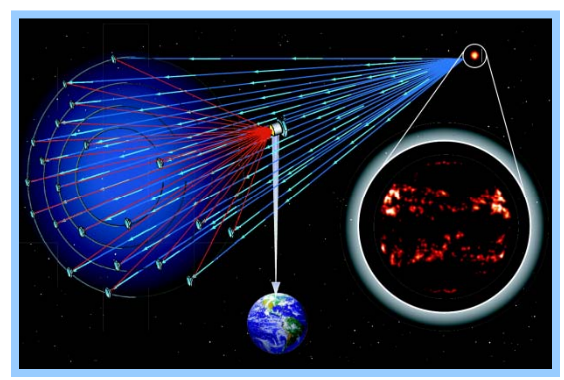
Precision Formation Flying Missions and Technologies

Daniel P. Scharf, Senior Engineer
Lead Engineer, TPF-I Formation Flying

Formation Flying



- <u>Formation</u>: S/C coupled by automatic feedback control with direct or indirect coupling between all S/C
- Tightest requirements for synthetic apertures
  - Driver is stroke limitations of optics
- GEO Sparse Aperture: DARPA LASSO
  - Millimeter-level error box
  - Arcsec-level attitude control
- Deep Space Nulling Interferometer: TPF-I
  - Sub-cm to several centimeter error box
  - Arcsec to sub-arcmin attitude control
- Deep Space Fizeau Synthetic Aperture: Stellar Imager
  - Sub-cm-level error box
  - Up to 32 S/C = LARGE formation
  - Arcsec to sub-arcmin attitude control

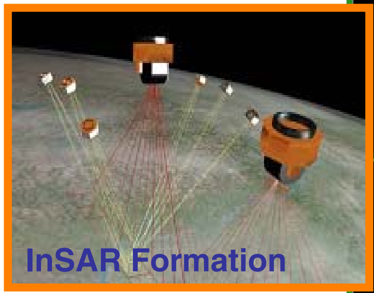


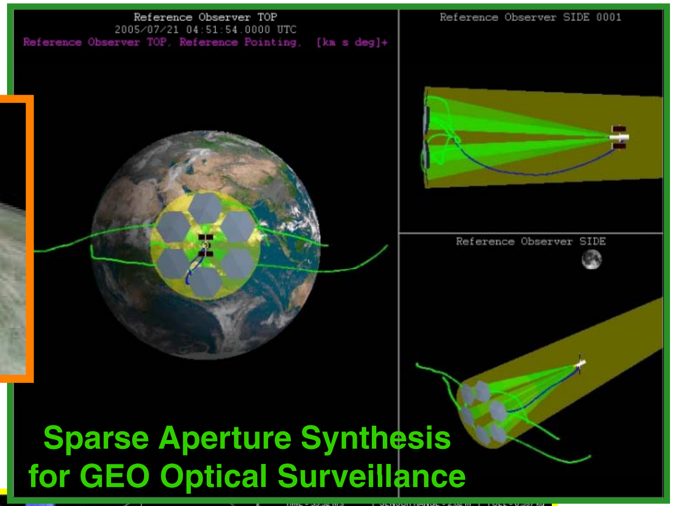
JPL focus on partnering

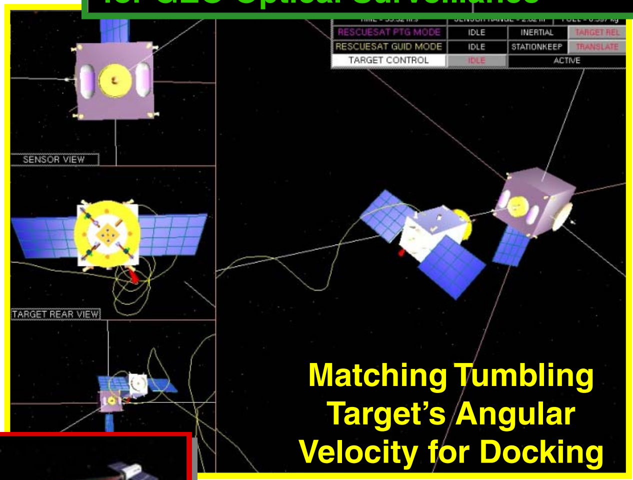
ninth Briefing for Industry

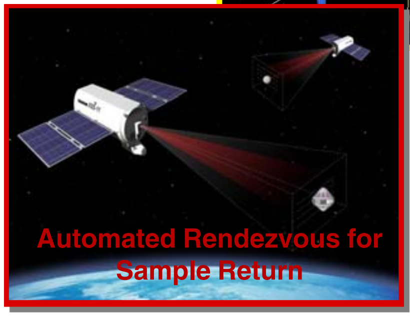
Applications

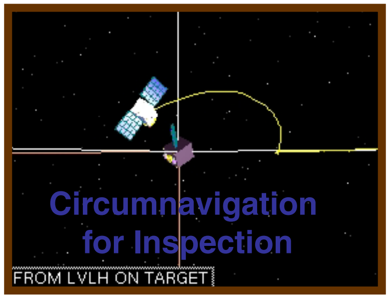
- Aperture Synthesis
  - Exoplanet detection and characterization
  - Astrophysics
  - Surveillance
  - Communications
  - Synthetic Aperture Radar (SAR)
    - Interferometric SAR (InSAR)
- Automated Rendezvous and Proximity/Docking Operations
  - Lunar/Martian Sample Return
  - On-orbit Manufacturing
  - On-orbit Assembly
  - On-orbit Servicing
  - Reconnaissance of Space Assets







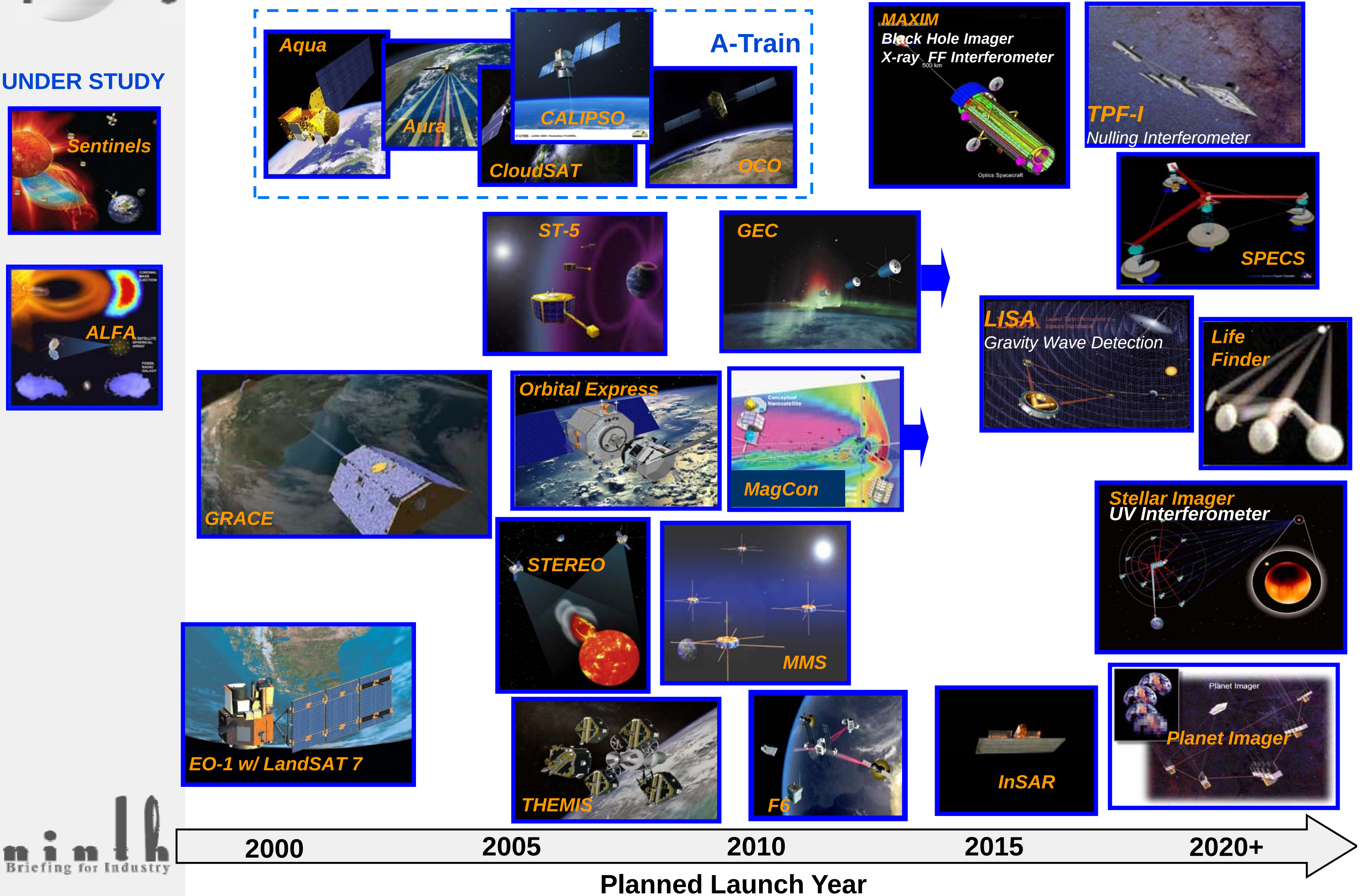




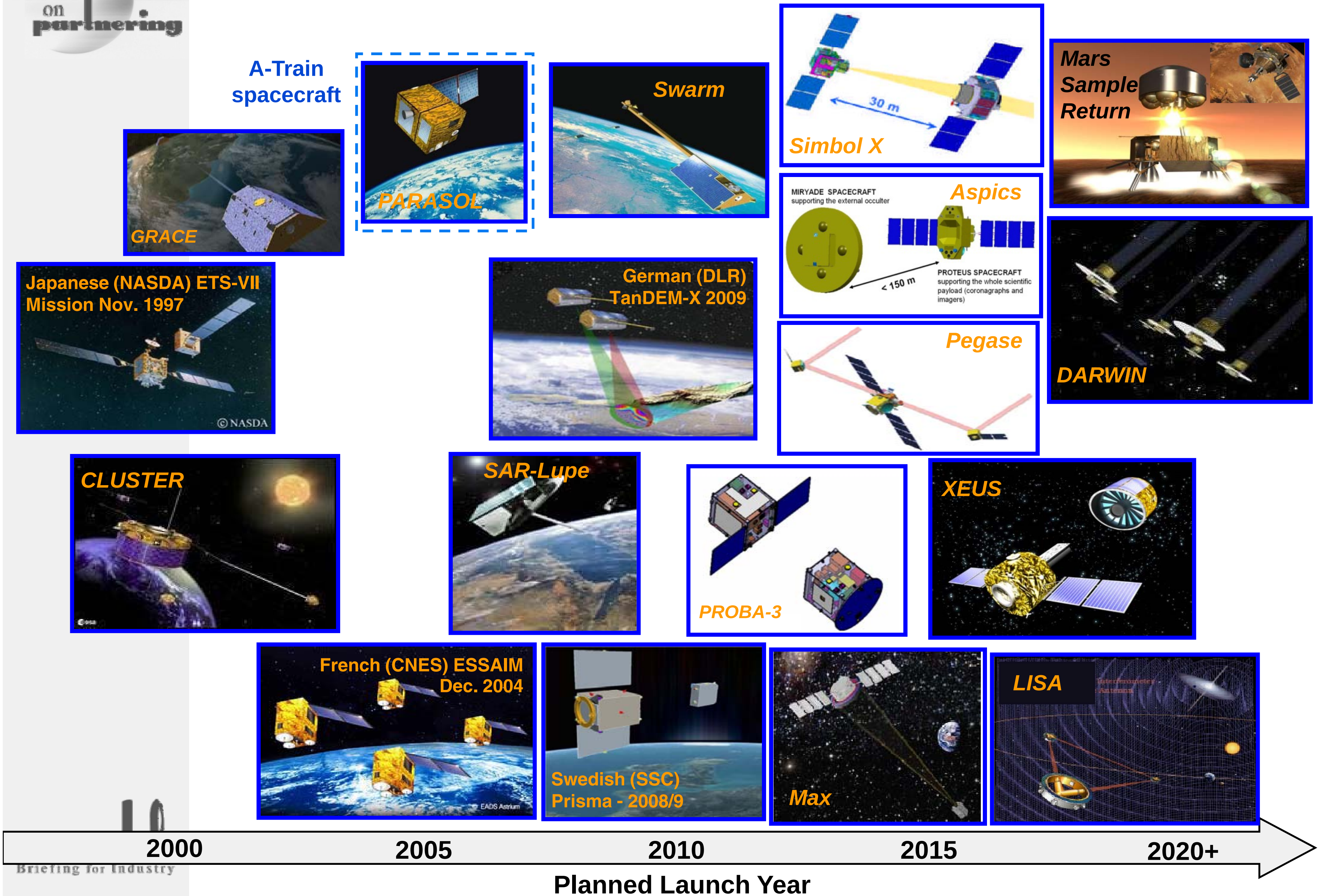
Manufacturing and Assembly of a Sparse Aperture

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

U.S. Distributed Missions



Non-U.S. Distributed Missions

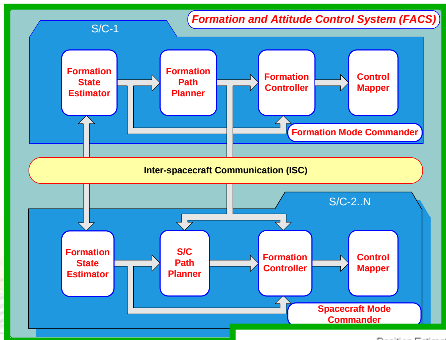


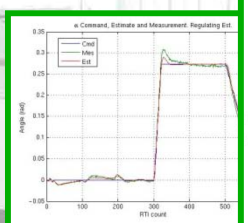
Technology Challenges

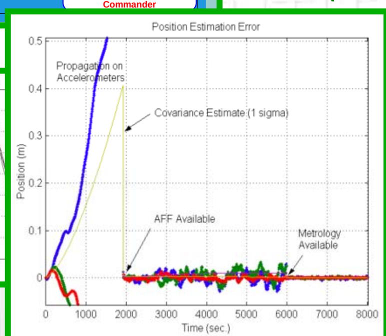
- **Formation guidance and control**
  - Synchronous reconfiguration and reorientation
  - Scalable decentralized/distributed guidance, control, and estimation
  - Relative position and attitude control for precision interferometry
- **High-precision and large-FOV sensors**
- **Extremely high-precision, low noise thrusters and wheels**
- **Scalable inter-spacecraft communication**
- **High-speed distributed computing, data management and autonomy**
  - Collaborative behavior
  - Autonomous fault detection and recovery
  - Coordinated instrument and science planning/processing
  - Efficient numerical integrators which handle large scale variations in states (relative position and attitude)
- **High-fidelity modeling and distributed real-time simulation**
  - Eventually including payloads
- **HW Testbeds**
  - 6DOF for development and ground validation

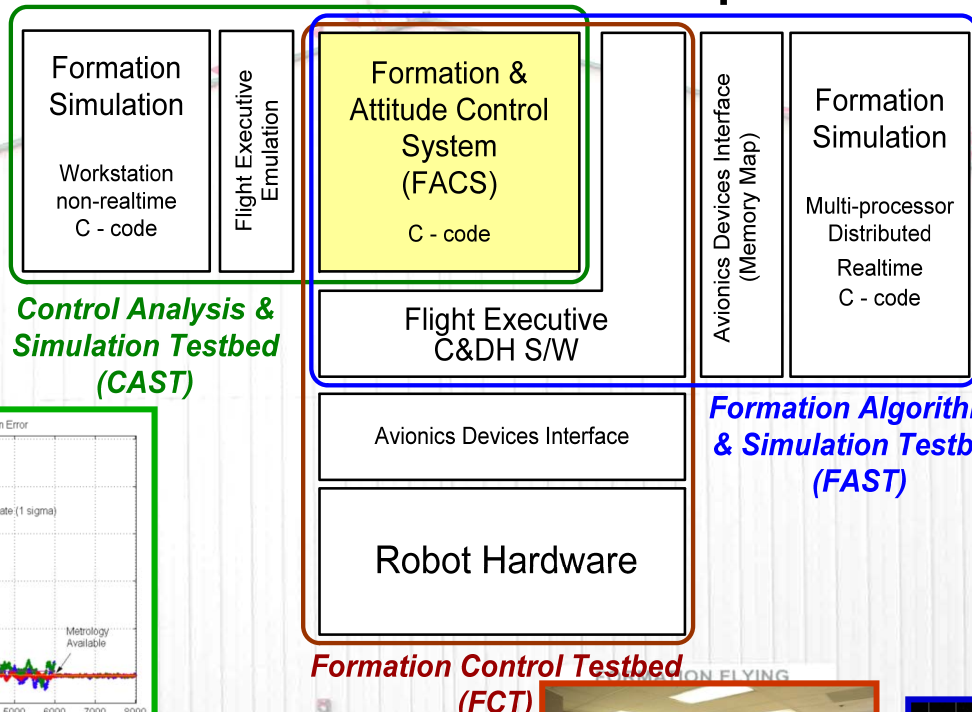
Summary of Formation Test Facilities at JPL

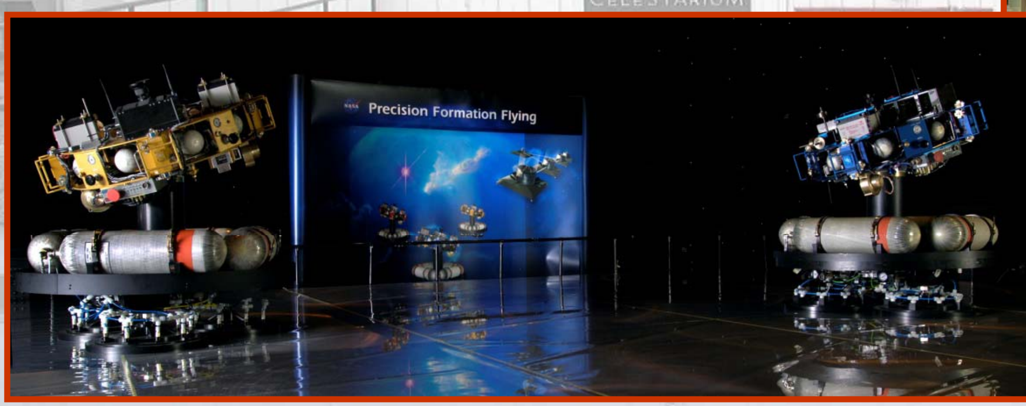
High-fidelity, flight-like, ground-based capability to simulate and validate end-to-end multi-spacecraft missions

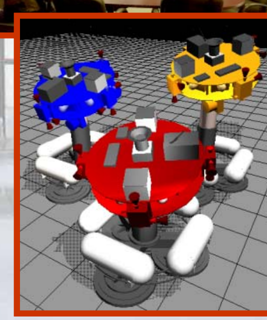


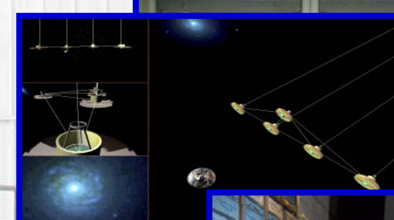


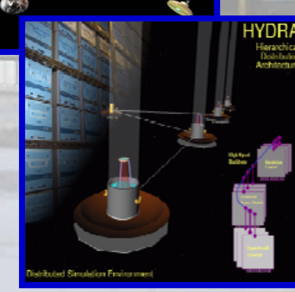












Collaborative System Demonstrations

Summary

- Many new and challenging distributed spacecraft missions and concepts
  - New capabilities, new discoveries, new science
- Intelligent space vehicles needed with increased autonomy
  - Operate distributed spacecraft as a single entity with a single operations team
- Distributed, collaborative systems in space will need
  - New hardware, GNC methodologies, system development approaches, and system architectures
- New testbed concepts, testing environments, and flight demonstrations key to success
- Significant increase in non-US distributed spacecraft technology investment and planned flights

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